Validation of cardiac strain estimation from 3D-tagged magnetic resonance images using finite element image correlation

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VALIDATION OF CARDIAC STRAIN ESTIMATION FROM 3D-TAGGED MAGNETIC RESONANCE IMAGES USING FINITE ELEMENT IMAGE CORRELATION

Ezgi Berberoglu[1,2,3], Christian Stoeck[1], Sebastian Kozerke[1], and Martin Genet[2,3,1]
1 Institute for Biomedical Engineering, University and ETH Zurich, Switzerland
2 Laboratoire de Mécanique des Solides, École Polytechnique / CNRS / Université Paris-Saclay, Palaiseau, France
3 MΞDISIM team, Inria / Université Paris-Saclay, Palaiseau, France

Introduction

Recent clinical and experimental studies have revealed that compared to global properties, regional changes allow for diagnosis and intervention in many cardiac diseases [1]. Speckle-tracking echocardiography and cardiovascular magnetic resonance (CMR) feature tracking are the most common techniques to assess regional cardiac motion. In addition, CMR tagging techniques are available in the research setting. Although global strain components are shown to be reproducible for both CMR approaches, regional heterogeneity is not detected robustly [1]. Moreover, strain computation has been shown to underestimate the radial component [2]. The objective of the present work is to extend and validate the recently proposed finite element digital image correlation method by Genet et al. for strain quantification from 3D tagged images [3].

Methods

The finite element-based digital image correlation tool used in this study [3] utilizes a mechanical regularizer, penalizing any deviation from mechanical equilibrium for strain computation. In this work, what we improve is to project the images onto the mesh, and then interpolate and differentiate, instead of simply interpolating image intensities and gradients at the mesh integration points [3]. This allows for a higher robustness with respect to image discretization by taking into account only the voxels within the mesh. Then, synthetic 3D-tagged images are generated from a reference biomechanical model of the left ventricle [4, 5]. The proposed image correlation method is run on the synthetic tagged images, and the obtained strains are compared to the ground truth of the biomechanical model. Additionally, the effect of image resolution and noise are investigated to understand the limits of strain analysis on tagged images.

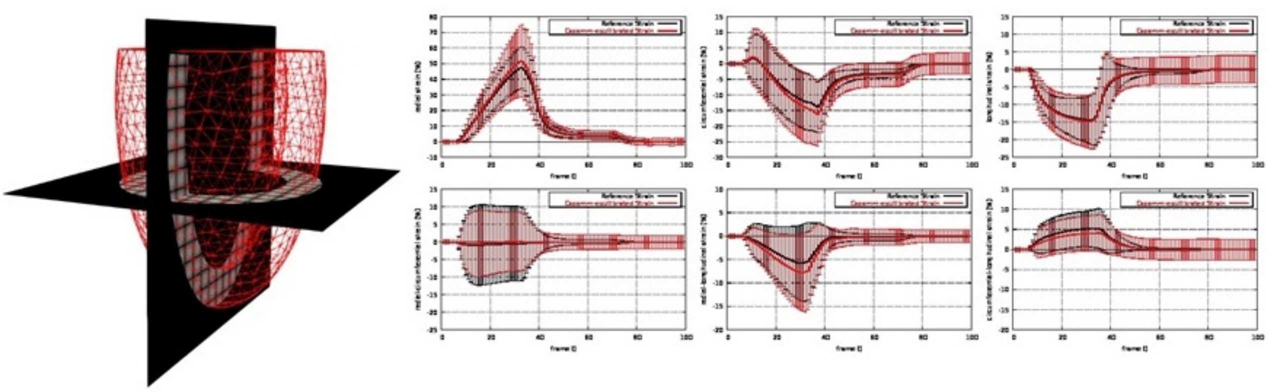

Figure 1. Reference 3D left ventricular mesh superimposed with the slices taken from the generated synthetic tagged images on two different planes (left). Comparison of reference principal and shear strain components obtained from the analysis of the biomechanical model with the preliminary results taken from running the image correlation tool on synthetic images (right).

Results

We validate our image correlation tool on tagged images after demonstrating that strain components for synthetic images match with the reference results (Figure 1). Then, we run analysis on resampled images and observed a deviation from the reference strain as we increase the downsampling factor. Compared to the reference, using downsampling factors of 2, 4, and 16 results in a deviation of peak radial strain by 2%, 6%, and 10%, respectively while the other strain components do not change significantly. We also observe a similar trend when we run our simulations using images with different signal-to-noise ratio.

References

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